

- 1 -

TITLE OF THE INVENTION

METHOD AND APPARATUS FOR EXECUTING PLURAL
PROCESSES ON A MICROELECTRONIC WORKPIECE AT A SINGLE
PROCESSING STATION

CROSS-REFERENCE TO RELATED APPLICATIONS

Not Applicable

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH
OR DEVELOPMENT

Not Applicable

BACKGROUND OF THE INVENTION

The fabrication of microelectronic components from a workpiece, such as a semiconductor wafer substrate, polymer substrate, etc., involves a substantial number of processes. There are a number of different processing operations performed on the workpiece to fabricate the microelectronic component(s). Such operations include, for example, material deposition, patterning, doping, chemical mechanical polishing, electropolishing, and heat treatment.

Material deposition processing involves depositing thin layers of electronic material to the surface of the workpiece (hereinafter described as, but not limited to, a semiconductor wafer). Patterning provides removal of selected portions of these added layers. Doping of the semiconductor wafer is the process of adding impurities known as "dopants" to the selected portions of the wafer to

- 2 -

alter the electrical characteristics of the substrate material. Heat treatment of the semiconductor wafer involves heating and/or cooling the wafer to achieve specific process results. Chemical mechanical polishing involves the removal of material through a combined chemical/mechanical process while electropolishing involves the removal of material from a workpiece surface using electrochemical reactions.

Numerous processing devices, known as processing "tools", have been developed to implement the foregoing processing operations. These tools take on different configurations depending on the type of workpiece used in the fabrication process and the process or processes executed by the tool. One tool configuration, known as the Equinox(R) wet processing tool and available from Semitool, Inc., of Kalispell, Montana, includes one or more workpiece processing stations that utilize a workpiece holder and a process bowl or container for implementing wet processing operations. Such wet processing operations include electroplating, etching, cleaning, electroless deposition, electropolishing, etc.

In accordance with one configuration of the foregoing Equinox(R) tool, the workpiece holder and the process bowl are disposed proximate one another and function to bring the semiconductor wafer held by the workpiece holder into contact with a processing fluid disposed in the process bowl and forming a processing chamber.

Conventional workpiece processors have utilized various techniques to bring the processing fluid into contact with the surface of the workpiece in a

- 3 -

controlled manner. For example, the processing fluid may be brought into contact with the surface of the workpiece using a controlled spray. In other types of processes, such as in partial or full immersion processing, the processing fluid resides in a bath and at least one surface of the workpiece is brought into contact with or below the surface of the processing fluid.

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65
66
67
68
69
70
71
72
73
74
75
76
77
78
79
80
81
82
83
84
85
86
87
88
89
90
91
92
93
94
95
96
97
98
99
100
101
102
103
104
105
106
107
108
109
110
111
112
113
114
115
116
117
118
119
120
121
122
123
124
125
126
127
128
129
130
131
132
133
134
135
136
137
138
139
140
141
142
143
144
145
146
147
148
149
150
151
152
153
154
155
156
157
158
159
160
161
162
163
164
165
166
167
168
169
170
171
172
173
174
175
176
177
178
179
180
181
182
183
184
185
186
187
188
189
190
191
192
193
194
195
196
197
198
199
200
201
202
203
204
205
206
207
208
209
210
211
212
213
214
215
216
217
218
219
220
221
222
223
224
225
226
227
228
229
230
231
232
233
234
235
236
237
238
239
240
241
242
243
244
245
246
247
248
249
250
251
252
253
254
255
256
257
258
259
260
261
262
263
264
265
266
267
268
269
270
271
272
273
274
275
276
277
278
279
280
281
282
283
284
285
286
287
288
289
290
291
292
293
294
295
296
297
298
299
300
301
302
303
304
305
306
307
308
309
310
311
312
313
314
315
316
317
318
319
320
321
322
323
324
325
326
327
328
329
330
331
332
333
334
335
336
337
338
339
340
341
342
343
344
345
346
347
348
349
350
351
352
353
354
355
356
357
358
359
360
361
362
363
364
365
366
367
368
369
370
371
372
373
374
375
376
377
378
379
380
381
382
383
384
385
386
387
388
389
390
391
392
393
394
395
396
397
398
399
400
401
402
403
404
405
406
407
408
409
410
411
412
413
414
415
416
417
418
419
420
421
422
423
424
425
426
427
428
429
430
431
432
433
434
435
436
437
438
439
440
441
442
443
444
445
446
447
448
449
450
451
452
453
454
455
456
457
458
459
460
461
462
463
464
465
466
467
468
469
470
471
472
473
474
475
476
477
478
479
480
481
482
483
484
485
486
487
488
489
490
491
492
493
494
495
496
497
498
499
500
501
502
503
504
505
506
507
508
509
510
511
512
513
514
515
516
517
518
519
520
521
522
523
524
525
526
527
528
529
530
531
532
533
534
535
536
537
538
539
540
541
542
543
544
545
546
547
548
549
550
551
552
553
554
555
556
557
558
559
560
561
562
563
564
565
566
567
568
569
570
571
572
573
574
575
576
577
578
579
580
581
582
583
584
585
586
587
588
589
590
591
592
593
594
595
596
597
598
599
600
601
602
603
604
605
606
607
608
609
610
611
612
613
614
615
616
617
618
619
620
621
622
623
624
625
626
627
628
629
630
631
632
633
634
635
636
637
638
639
640
641
642
643
644
645
646
647
648
649
650
651
652
653
654
655
656
657
658
659
660
661
662
663
664
665
666
667
668
669
670
671
672
673
674
675
676
677
678
679
680
681
682
683
684
685
686
687
688
689
690
691
692
693
694
695
696
697
698
699
700
701
702
703
704
705
706
707
708
709
710
711
712
713
714
715
716
717
718
719
720
721
722
723
724
725
726
727
728
729
730
731
732
733
734
735
736
737
738
739
740
741
742
743
744
745
746
747
748
749
750
751
752
753
754
755
756
757
758
759
760
761
762
763
764
765
766
767
768
769
770
771
772
773
774
775
776
777
778
779
780
781
782
783
784
785
786
787
788
789
790
791
792
793
794
795
796
797
798
799
800
801
802
803
804
805
806
807
808
809
810
811
812
813
814
815
816
817
818
819
820
821
822
823
824
825
826
827
828
829
830
831
832
833
834
835
836
837
838
839
840
841
842
843
844
845
846
847
848
849
850
851
852
853
854
855
856
857
858
859
860
861
862
863
864
865
866
867
868
869
870
871
872
873
874
875
876
877
878
879
880
881
882
883
884
885
886
887
888
889
890
891
892
893
894
895
896
897
898
899
900
901
902
903
904
905
906
907
908
909
910
911
912
913
914
915
916
917
918
919
920
921
922
923
924
925
926
927
928
929
930
931
932
933
934
935
936
937
938
939
940
941
942
943
944
945
946
947
948
949
950
951
952
953
954
955
956
957
958
959
960
961
962
963
964
965
966
967
968
969
970
971
972
973
974
975
976
977
978
979
980
981
982
983
984
985
986
987
988
989
990
991
992
993
994
995
996
997
998
999
1000
1001
1002
1003
1004
1005
1006
1007
1008
1009
1010
1011
1012
1013
1014
1015
1016
1017
1018
1019
1020
1021
1022
1023
1024
1025
1026
1027
1028
1029
1030
1031
1032
1033
1034
1035
1036
1037
1038
1039
1040
1041
1042
1043
1044
1045
1046
1047
1048
1049
1050
1051
1052
1053
1054
1055
1056
1057
1058
1059
1060
1061
1062
1063
1064
1065
1066
1067
1068
1069
1070
1071
1072
1073
1074
1075
1076
1077
1078
1079
1080
1081
1082
1083
1084
1085
1086
1087
1088
1089
1090
1091
1092
1093
1094
1095
1096
1097
1098
1099
1100
1101
1102
1103
1104
1105
1106
1107
1108
1109
1110
1111
1112
1113
1114
1115
1116
1117
1118
1119
1120
1121
1122
1123
1124
1125
1126
1127
1128
1129
1130
1131
1132
1133
1134
1135
1136
1137
1138
1139
1140
1141
1142
1143
1144
1145
1146
1147
1148
1149
1150
1151
1152
1153
1154
1155
1156
1157
1158
1159
1160
1161
1162
1163
1164
1165
1166
1167
1168
1169
1170
1171
1172
1173
1174
1175
1176
1177
1178
1179
1180
1181
1182
1183
1184
1185
1186
1187
1188
1189
1190
1191
1192
1193
1194
1195
1196
1197
1198
1199
1200
1201
1202
1203
1204
1205
1206
1207
1208
1209
1210
1211
1212
1213
1214
1215
1216
1217
1218
1219
1220
1221
1222
1223
1224
1225
1226
1227
1228
1229
1230
1231
1232
1233
1234
1235
1236
1237
1238
1239
1240
1241
1242
1243
1244
1245
1246
1247
1248
1249
1250
1251
1252
1253
1254
1255
1256
1257
1258
1259
1260
1261
1262
1263
1264
1265
1266
1267
1268
1269
1270
1271
1272
1273
1274
1275
1276
1277
1278
1279
1280
1281
1282
1283
1284
1285
1286
1287
1288
1289
1290
1291
1292
1293
1294
1295
1296
1297
1298
1299
1300
1301
1302
1303
1304
1305
1306
1307
1308
1309
1310
1311
1312
1313
1314
1315
1316
1317
1318
1319
1320
1321
1322
1323
1324
1325
1326
1327
1328
1329
1330
1331
1332
1333
1334
1335
1336
1337
1338
1339
1340
1341
1342
1343
1344
1345
1346
1347
1348
1349
1350
1351
1352
1353
1354
1355
1356
1357
1358
1359
1360
1361
1362
1363
1364
1365
1366
1367
1368
1369
1370
1371
1372
1373
1374
1375
1376
1377
1378
1379
1380
1381
1382
1383
1384
1385
1386
1387
1388
1389
1390
1391
1392
1393
1394
1395
1396
1397
1398
1399
1400
1401
1402
1403
1404
1405
1406
1407
1408
1409
1410
1411
1412
1413
1414
1415
1416
1417
1418
1419
1420
1421
1422
1423
1424
1425
1426
1427
1428
1429
1430
1431
1432
1433
1434
1435
1436
1437
1438
1439
1440
1441
1442
1443
1444
1445
1446
1447
1448
1449
1450
1451
1452
1453
1454
1455
1456
1457
1458
1459
1460
1461
1462
1463
1464
1465
1466
1467
1468
1469
1470
1471
1472
1473
1474
1475
1476
1477
1478
1479
1480
1481
1482
1483
1484
1485
1486
1487
1488
1489
1490
1491
1492
1493
1494
1495
1496
1497
1498
1499
1500
1501
1502
1503
1504
1505
1506
1507
1508
1509
1510
1511
1512
1513
1514
1515
1516
1517
1518
1519
1520
1521
1522
1523
1524
1525
1526
1527
1528
1529
1530
1531
1532
1533
1534
1535
1536
1537
1538
1539
1540
1541
1542
1543
1544
1545
1546
1547
1548
1549
1550
1551
1552
1553
1554
1555
1556
1557
1558
1559
1560
1561
1562
1563
1564
1565
1566
1567
1568
1569
1570
1571
1572
1573
1574
1575
1576
1577
1578
1579
1580
1581
1582
1583
1584
1585
1586
1587
1588
1589
1590
1591
1592
1593
1594
1595
1596
1597
1598
1599
1600
1601
1602
1603
1604
1605
1606
1607
1608
1609
1610
1611
1612
1613
1614
1615
1616
1617
1618
1619
1620
1621
1622
1623
1624
1625
1626
1627
1628
1629
1630
1631
1632
1633
1634
1635
1636
1637
1638
1639
1640
1641
1642
1643
1644
1645
1646
1647
1648
1649
1650
1651
1652
1653
1654
1655
1656
1657
1658
1659
1660
1661
1662
1663
1664
1665
1666
1667
1668
1669
1670
1671
1672
1673
1674
1675
1676
1677
1678
1679
1680
1681
1682
1683
1684
1685
1686
1687
1688
1689
1690
1691
1692
1693
1694
1695
1696
1697
1698
1699
1700
1701
1702
1703
1704
1705
1706
1707
1708
1709
1710
1711
1712
1713
1714
1715
1716
1717
1718
1719
1720
1721
1722
1723
1724
1725
1726
1727
1728
1729
1730
1731
1732
1733
1734
1735
1736
1737
1738
1739
1740
1741
1742
1743
1744
1745
1746
1747
1748
1749
1750
1751
1752
1753
1754
1755
1756
1757
1758
1759
1760
1761
1762
1763
1764
1765
1766
1767
1768
1769
1770
1771
1772
1773
1774
1775
1776
1777
1778
1779
1780
1781
1782
1783
1784
1785
1786
1787
1788
1789
1790
1791
1792
1793
1794
1795
1796
1797
1798
1799
1800
1801
1802
1803
1804
1805
1806
1807
1808
1809
1810
1811
1812
1813
1814
1815
1816
1817
1818
1819
1820
1821
1822
1823
1824
1825
1826
1827
1828
1829
1830
1831
1832
1833
1834
1835
1836
1837
1838
1839
1840
1841
1842
1843
1844
1845
1846
1847
1848
1849
1850
1851
1852
1853
1854
1855
1856
1857
1858
1859
1860
1861
1862
1863
1864
1865
1866
1867
1868
1869
1870
1871
1872
1873
1874
1875
1876
1877
1878
1879
1880
1881
1882
1883
1884
1885
1886
1887
1888
1889
1890
1891
1892
1893
1894
1895
1896
1897
1898
1899
1900
1901
1902
1903
1904
1905
1906
1907
1908
1909
1910
1911
1912
1913
1914
1915
1916
1917
1918
1919
1920
1921
1922
1923
1924
1925
1926
1927
1928
1929
1930
1931
1932
1933
1934
1935
1936
1937
1938
1939
1940
1941
1942
1943
1944
1945
1946
1947
1948
1949
1950
1951
1952
1953
1954
1955
1956
1957
1958
1959
1960
1961
1962
1963
1964
1965
1966
1967
1968
1969
1970
1971
1972
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
2031
2032
2033
2034
2035
2036
2037
2038
2039
2040
2041
2042
2043
2044
2045
2046
2047
2048
2049
2050
2051
2052
2053
2054
2055
2056
2057
2058
2059
2060
2061
2062
2063
2064
2065
2066
2067
2068
2069
2070
2071
2072
2073
2074
2075
2076
2077
2078
2079
2080
2081
2082
2083
2084
2085
2086
2087
2088
2089
2090
2091
2092
2093
2094
2095
2096
2097
2098
2099
2100
2101
2102
2103
2104
2105
2106
2107
2108
2109
2110
2111
2112
2113
2114
2115
2116
2117
2118
2119
2120
2121
2122
2123
2124
2125
2126
2127
2128
2129
2130
2131
2132
2133
2134
2135
2136
2137
2138
2139
2140
2141
2142
2143
2144
2145
2146
2147
2148
2149
2150
2151
2152
2153
2154
2155
2156
2157
2158
2159
2160
2161
2162
2163
2164
2165
2166
2167
2168
2169
2170
2171
2172
2173
2174
2175
2176
2177
2178
2179
2180
2181
2182
2183
2184
2185
2186
2187
2188
2189
2190
2191
2192
2193
2194
2195
2196
2197
2198
2199
2200
2201
2202
2203
2204
2205
2206
2207
2208
2209
2210

BRIEF SUMMARY OF THE INVENTION

An apparatus for processing a microelectronic workpiece is set forth. The apparatus comprises a workpiece support adapted to hold the microelectronic workpiece and a processing container adapted to receive the microelectronic workpiece held by the workpiece support. A drive mechanism is connected to drive the processing container and the workpiece support holding the microelectronic workpiece relative to one another so that the microelectronic workpiece may be moved to a plurality of workpiece processing positions. At least two chemical delivery systems are employed. A first chemical delivery system is used to provide at least one processing fluid to the processing container for application to the microelectronic workpiece when the microelectronic workpiece is in a first one of the plurality of workpiece processing positions while a second chemical delivery system is used to provide at least one processing fluid to the processing container for application to the microelectronic workpiece when the microelectronic workpiece is in a second one of the plurality of microelectronic workpiece processing positions. The apparatus also includes at least two chemical collector systems. A first chemical collector system is used to assist in at least partially removing spent processing fluid provided by the first chemical delivery system while the microelectronic workpiece is in the first one of the plurality of workpiece processing positions. Similarly, a second chemical collector system is used to assist in at least partially removing spent processing fluid provided by the second chemical delivery system from the processing

container while the microelectronic workpiece is in the second one of the plurality of microelectronic workpiece processing positions. In accordance with one embodiment, the apparatus is particularly adapted to execute an immersion process, such as electroplating, and a spraying process, such as an in-situ rinse.

- 6 -

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

FIGURE 1 is a perspective view of a reactor constructed in accordance with one embodiment of the present invention.

FIGURE 2 is a cross-sectional view of the reactor illustrated in FIGURE 1.

FIGURE 3 is a further cross-sectional view of the reactor illustrated in FIGURE 1.

FIGURES 4 and 5 illustrate the orientation of the processing head and corresponding workpiece during a workpiece loading operation.

FIGURES 6 – 9 are cross-sectional views of the reactor of FIGURE 1 illustrating the microelectronic workpiece at various processing positions within the processing container.

FIGURES 10 and 11 are cross-sectional views of the reactor of FIGURE 1 illustrating the microelectronic workpiece at various angular positions within the second processing portion of the processing container so as to vary the position of initial contact of a stream of processing fluid with a surface of the microelectronic workpiece.

- 7 -

DETAILED DESCRIPTION OF THE INVENTION

With reference to FIGURES 1 -3, there is shown a reactor assembly 20 for processing a microelectronic workpiece, such as a semiconductor wafer 25 or the like. Generally stated, the reactor assembly 20 is comprised of a reactor head, shown generally at 30, that includes one or more components used to support the workpiece 25. Additionally, the reactor assembly 20 includes a corresponding reactor container, shown generally at 35, that receives one or more processing fluids from one or more chemical delivery systems.

The reactor head 30 of the reactor 20 is preferably comprised of a stationary assembly 40 and, optionally, a rotor assembly 45 that is driven by a corresponding rotor motor 47. Rotor assembly 45 may be configured to receive and carry an associated wafer 25 or like workpiece, position the workpiece in a process-side down orientation within reactor container 35, and to rotate or spin the workpiece. The rotor assembly 45 and/or reactor head 30 may also be used to elevate the workpiece after initial contact with a processing liquid so that only a meniscus of the processing fluid contacts the side of the workpiece that is to be processed. This also falls within the ambit of an immersion process.

The reactor head 30 is mounted on a lift/rotate apparatus 50 which is configured to rotate the reactor head 30 from an upwardly-facing disposition in which it receives the wafer to be plated, to a downwardly facing disposition in which the surface of the wafer to be processed is positioned so that it may be brought into contact with a processing fluid, such as an electroplating solution, in

- 8 -

reactor container 35. A robotic arm (not illustrated), which may include an end effector, is typically employed for placing the workpiece 25 in position on the rotor assembly 45, and for removing the processed wafer from within the rotor assembly 45 after processing is complete.

Lift/rotate apparatus 50 is preferably capable of moving the workpiece 25 to a plurality of positions with respect to reactor container 35. More particularly, the lift/rotate apparatus 50 may be capable of moving the reactor head 30 and the corresponding workpiece 25 in a vertical fashion toward and away from the reactor container 35. Such vertical motion may be directed by a programmable control system 55 or the like. Programmable control system 55 may also be used to adjust the spin rate of the rotor motor 47.

Although lift/rotate apparatus 50 of the disclosed embodiment has the ability to rotate reactor head 30 for presentation of the workpiece 25 by a corresponding robot in a process-side up orientation, it will be recognized that apparatus 50 need not have such rotation abilities. Rather, the workpiece 25 may be presented to the reactor head 30 by the corresponding robot in a process-side down orientation. In such instances, rotation of the workpiece to the process-side down orientation may take place on the corresponding robot or another apparatus within the overall processing system.

The reactor container 35 includes a first processing portion, shown generally at 60, that is configured to execute a first process in which one or more processing fluids are delivered to treat at least one surface of the workpiece 25. In

- 9 -

the illustrated embodiment, for exemplary purposes, first processing portion 60 of container 35 is configured to execute an electroplating process. However, the first processing portion 60 of container 35 may be alternatively configured to execute any number of different processes. Such processes include, but are not limited to, immersion processes, vapor processes, spray processes, gaseous processes, etc.

Pursuant to executing an electroplating process in the first processing portion 60, container 35 is configured to provide a flow of an electroplating solution to one or more surfaces of the workpiece 25. To this end, container 35 includes an interior container 65 having an inlet 70 through which a flow of electroplating solution is provided. The electroplating solution provided through inlet 70 flows through the interior container 65 and overflows therefrom about an upper weir 75 into an exterior overflow region 77. This type of reactor assembly is particularly suited for effecting electroplating of semiconductor wafers or like workpieces, in which an electrically conductive, thin-film layer of the wafer is electroplated with a blanket or patterned metallic layer while in a process-side down orientation.

Within the interior container 65 there is an anode assembly, shown generally at 80, having one or more anodes 85 that is in the electrical contact with the electroplating solution (although the illustrated embodiment utilizes a single anode 85). The one or more anodes 85 are electrically connected to a source of electroplating power (not shown) through one or more electric conductive structures. The anode assembly 80 may be constructed in the manner set forth in

- 10 -

PCT Application No. PCT/US99/15430, entitled "REACTOR VESSEL HAVING IMPROVED CUP, ANODE AND CONDUCTOR ASSEMBLY", filed July 9, 1999 (Attorney Docket No. SEM4492P0200PC; Corporate Docket No. P98-0017PCT), the teachings of which are hereby incorporated by reference.

An alternative reactor container suitable for immersion processing is set forth in U.S.S.N. 60/143,769, entitled "workpiece processor having improved processing chamber", filed July 12, 1999 (Attorney Docket No. SEM4492P0831US; Corporate Docket No. P99-0034).

In those instances in which the reactor is to be used in an electroplating process, the rotor assembly 45 of head 30 may include one or more cathode contacts that provide electroplating power to the surface of the wafer. In the illustrated embodiment, a cathode contact assembly is shown generally at 90. This cathode contact assembly may be constructed in accordance with the teachings of PCT Application No. PCT/US99/15847, entitled "METHOD AND APPARATUS FOR COPPER PLATING USING ELECTROLESS PLATING AND ELECTROPLATING", filed July 12, 1999 (Attorney Docket No. SEM4492P0571PC; Corporate Docket No. P99-0025PCT). Although the various contact configurations illustrated in that patent application provide electroplating power directly to the side of the wafer that is to be processed, it will be recognized that backside contact may be implemented in lieu of front side contact when the substrate is conductive or other means are provided to electrically connect the backside of the workpiece with the process side thereof. The contact

- 11 -

assembly 90 may be operated between an open state that allows the wafer to be placed on the rotor assembly 45, and a closed state that secures the wafer to the rotor assembly and brings the electrically conductive components of the contact assembly 85 into electrical engagement with the surface of the wafer that is to be plated.

Processing container 35 also includes a second processing portion, shown generally at 95, that is adapted to execute a further process on one or more surfaces of the microelectronic workpiece 25. In the illustrated embodiment, the second processing portion 95 is adapted to execute a process in which a processing fluid is provided at the downward facing surface of the workpiece 25. To this end, one or more nozzles 100 are provided in the second processing portion 95 and are directed toward the workpiece 25.

It is often desirable to at least partially inhibit mixing of the processing chemicals used in different processing steps. Reactor container 35 therefore includes separate collection systems for collecting spent processing fluids (e.g., processing fluids that have contacted one or more surfaces of the workpiece 25). With respect to the illustrated embodiment, the processing fluids used in processes carried out in the first processing portion 60 of reactor container 35 are liquids that overflow the weir 75 of the interior container 65 and enter the overflow region 77. After entering the overflow region 77, the processing chemicals are removed through one or more outlets that are in fluid

- 12 -

communication with the overflow region 77. The fluid exiting from the reactor container 35 subsequently undergoes disposal, recycling, constituent dosing, etc.

In those instances in which the processing fluid used in the first processing portion 60 is in a gaseous or vapor state, overflow region 77 may be connected to a vacuum source. Spent processing fluid may then be removed as it overflows the weir 75. As above, process fluid exiting from the reactor container 35 may subsequently undergo disposal, recycling, constituent dosing, etc..

A further collection system is used for collecting spent processing fluids employed in processes carried out in the second processing portion 95. The further collection system, generally designated at 105, is provided in or proximate the second processing portion 95. In the illustrated embodiment, the first processing portion 60 of reactor container 35 is disposed vertically below the second processing portion 95 and, further, is open to the second processing portion 95. These factors complicate the collection process as it is to be executed by the further collection system. For example, if a liquid is used as the processing fluid in the second processing portion 95 and delivered to a surface of the microelectronic workpiece 25, liquid drops can readily enter and adversely effect the first processing portion 60. Although small amounts of the liquid may be tolerated in the first processing portion 60, the substantial amounts of the liquid that are often introduced during spray processing or like can and often will reduce the effectiveness of the processing that takes place in the first processing portion 60.

- 13 -

To overcome the foregoing problems, the further collection system 105 is in the form of one or more fluid channels, shown generally at 110, that are disposed at the inner periphery of reactor container 35. As shown, the fluid channels 110 are located in the second processing portion 95 proximate the position of the workpiece 25 as it undergoes processing in the second processing portion 95. Each fluid channel, as illustrated in FIGURES 2 and 3, may be defined by a splash wall 115 and a retainer wall 120. The splash wall 115 and retainer wall 120 may each be disposed at an angle with respect to horizontal. The manner in which this further collection system functions will become clearer in connection with the operational description below.

In operation, the reactor head 30 is elevated and rotated by the lift/rotate apparatus 50 to a loading position, illustrated in FIGURE 4, that is located above the reactor container 35. While in this position, a workpiece 25 is placed upon rotor assembly 45 with the side of the workpiece that is to be electroplated facing upward. The contact assembly 90 of the rotor assembly 45 is then actuated to grip the workpiece 25 and secure it therewith. This actuation also causes the contact assembly 90 to make electrical contact with the workpiece 25 to supply power for the electroplating operation. As noted above, however, rotation of the reactor head 30 need not take place in apparatus in which the workpiece 25 is rotated to a process-side down position prior to introduction of the workpiece 25 to the rotor assembly 45.

- 14 -

Once the workpiece 25 has been secured with the rotor assembly 45, the lift/rotate apparatus 50 is directed by the control system 55 to rotate the reactor head 30 so that the surface of the workpiece that is to be processed is faced downward, as illustrated in FIGURE 5 . With the workpiece 25 in this state, the control system 55 directs the lift/rotate apparatus 50 to drive the rotor assembly 45 and the corresponding workpiece to a first workpiece processing position within the reactor container 35. This first workpiece processing position may be located in either the first processing portion 60 or the second processing portion 95 of the reactor container 35. For exemplary purposes, it will be assumed that processing will first take place in the first processing portion 60. As such, the lift/rotate apparatus 50 is directed by the control system 55 to take the necessary steps to bring the workpiece 25 to the position illustrated in FIGURE 6. In this position, at least the lower surface of the workpiece 25 is brought into contact with a flow of electroplating solution provided at the upper portion of interior container 65. Electroplating power is then provided to both the workpiece 25 and the anode 85 to affect electroplating of the surface. During the electroplating process, spent processing fluid is collected within the overflow region 77 and removed from the reactor container 35.

Once electroplating is completed in the first processing portion 60, the control system 55 directs the lift/rotate apparatus 50 to move the workpiece 25 to an intermediate position, designated generally at 57 of FIGURE 7. While at this position, the workpiece 25 is spun at a high rotation rate to fling off a bulk

- 15 -

portion of any excess electroplating solution. This reduces drag out and waste of the electroplating solution.

After the bulk portion of the excess electroplating solution has been flung off, the control system 55 directs the lift/rotate apparatus 50 to move the workpiece 25 to a second processing position. Here, in the exemplary process, the second processing position is located in the second processing portion 95 of the reactor container 35. The lift/rotate apparatus 50 thus drives the workpiece 25 to the position illustrated in FIGURE 7. In this position, one or more further processing chemicals are provided from a chemical supply system to contact one or more surfaces of the workpiece 25. With respect to the specific embodiment disclosed herein, a liquid stream of a processing fluid, such as water that may or may not include additives, is provided through the one or more nozzles 100 to contact the lower surface of the workpiece 25 that has been electroplated. As the liquid stream is directed toward the workpiece surface, the rotor assembly 45 and corresponding workpiece 25 are rotated at a high rotation rate so that the liquid impinging on the workpiece surface is flung radially outward therefrom under the influence of centripetal acceleration. The liquid flung in this manner is collected by the further collection system 105. More particularly, the liquid flung in this manner contacts the splash wall 115 corresponding to the channel 110 that is immediately adjacent the lower surface of the workpiece 25, and proceeds downward therealong into the corresponding channel 110. Retainer wall 120, being disposed at an angle with respect to horizontal, assists in retaining the

- 16 -

accumulated liquid within the corresponding channel 110. One or more outlets 125 are placed in fluid communication with the channel 110 to allow the spent processing liquid to be removed from the reactor container 35. As such, the spent processing liquid used in the second processing portion 95 is effectively removed from the reactor container 35 by the further collection system 105, thereby minimizing the amount of the spent liquid that enters the first processing portion 60.

As can be seen in the FIGURES, a plurality of collection channels 110 may be used. In accordance with one embodiment of the present invention, all of the plurality of collection channels 110 can be connected to a common drain. Such a configuration is particularly useful in those instances in which a single processing fluid is employed for processing the workpiece when it is in the second processing portion 95. However, it may be desirable to process the workpiece 25 using more than one type of processing fluid in the second processing portion 95 while collecting the processing fluids separately. To this end, programmable control system 55 directs the lift/rotate apparatus 50 to a plurality of positions within the second processing portion 95. Here, those positions differ with respect to their vertical position within the reactor container 35.

A unique manner of delivering a fluid stream to the surface of a workpiece is illustrated in connection with FIGURES 7-9. As illustrated, the workpiece 25 is moved to a plurality of processing positions within the second

- 17 -

processing portion 95. With reference to FIGURE 7, the reactor head 30 is driven by the control system 55 to place the workpiece 25 at a first processing position within the second processing portion 95. In this position, nozzle 100 directs a stream of processing fluid 130 toward a central portion of the lower surface of the workpiece 25 at an upward angle. As the stream of processing fluid 130 is provided to the surface of workpiece 25, the control system 55 directs the reactor head 30 to move the workpiece 25 sequentially through the positions illustrated in FIGURES 7 through 9. Such movement through these positions can be executed in accordance with a controlled continuous velocity, a controlled velocity profile, or in discrete steps. As the workpiece 25 is moved to these various processing positions, the stream of processing fluid 130 from nozzle 100 is directed at a substantially fixed point in space. Since the stream 130 is fixed at an acute angle as the workpiece 25 is moved, the radial position at which the stream 130 contacts the workpiece 25 changes and approaches the periphery of the surface of workpiece 25. This is particularly useful when this apparatus configuration and method of operation are used in connection with electroplating operations, since the stream 130 may be comprised of deionized water and effectively "chase off" electroplating solution from surface of microelectronic workpiece 25.

As can be seen in the foregoing figures, a plurality of channels 110 are employed. Each channel 110 corresponds to one or more processing positions assumed by the workpiece 25 as it is processed in the second processing portion

- 18 -

95. In those instances in which a single processing fluid is used in the second processing portion 95, the channels 110 may be connected together and tied to a single outlet 135. However, it is also possible to provide different processing fluids to the surface of the workpiece 25 at different processing positions within the second processing portion 95. In such operations, channels 110 may be used to separately collect each of the processing fluids and provide them to separate outlets.

An alternative method (or additional method, if used in conjunction with the method described above) of delivering a stream of processing fluid to the downward facing surface of the workpiece 25 is illustrated in FIGURES 10 and 11. In accordance with this latter method, reactor head 30 is driven to a fixed position within second processing portion 95 by the lift/rotate apparatus 50 under the direction of control system 55. A stream of processing fluid is provided through one or more nozzles 100. Control system 55 directs lift/rotate apparatus 50 to rotate reactor head 30 through a plurality of angles so that the stream of processing fluid 130 makes initial contact with the lower surface of workpiece 25 at a plurality of portions thereof sequentially as a function of time. Again, workpiece 25 may be spun at a high rotation rate to fling off spent processing fluid into the fluid channels 110 of the further collection system 105 as the stream of processing fluid 130 is delivered to the surface of workpiece 25. Rotation of the reactor head 30 and corresponding workpiece 25 may be executed in accordance with a controlled motion profile, such as a controlled continuous or

- 19 -

variable rotation rate, between the starting and ending angular positions. Alternatively, the controlled motion profile may be in the form of discrete angular steps between the starting and ending angular positions.

FIGURES 10 and 11 illustrate starting and ending angular positions that may be employed, with FIGURE 10 illustrating the starting angular position and FIGURE 11 illustrating the ending angular position. In this illustrated embodiment, the stream of processing fluid 130 is initially directed to a central portion of the workpiece 25 as in FIGURE 10. Reactor head 30 and the corresponding workpiece 25 are then rotated through one or more angular positions to reach the ending angular position shown in FIGURE 11 in which the stream of processing fluid 130 is directed for initial contact with a peripheral portion of the workpiece 25.

Although, as noted above, the present invention is suitable for use in a wide range of microelectronic workpiece processes, it is particularly well-suited for use in microelectronic workpiece electroplating. After plating a wafer, the surface of the wafer that has been exposed to the plating solution is wetted with plating solution. The contact assembly and corresponding barrier seal are also wetted at the seal interface with the wafer. This condition is difficult to solve due to conflicting requirements. The wafer needs to remain wetted until the plating solution can be neutralized by deionized water or another neutralizer. The contact seal, on the other hand, needs the residual solution removed or dried to prevent migration of the plating solution to the sealed area, and ultimately behind

- 20 -

it, during product removal. Simply trying this residual plating solution is not an option to to the corrosive/oxidizing effect drying has on the plated film. Such problems are addressed by rinsing the wafer and seal interface before the wafer is removed from the reactor. Also, it has been found to be desirable to occasionally rinse the seal and electrical contact in the absence of a wafer to assist in preventing a buildup of copper salts.

Numerous modifications may be made to the foregoing system without departing from the basic teachings thereof. Although the present invention has been described in substantial detail with reference to one or more specific embodiments, those of skill in the art will recognize that changes may be made thereto without departing from the scope and spirit of the invention as set forth in the appended claims.